Tectonic evolution of east-dipping subduction zone in Caribbean

Late Cretaceous plume-induced subduction initiation along the southern margin of the Caribbean: Insights from numerical modeling

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In Short

- Numerical modeling of plume-induced subduction initiation
- Investigation of factors controlling the formation of one-sided subduction zone
- Study of different scenarios for initiation of the east-dipping subduction zone in Caribbean

Subduction zones characterize as the main components in plate tectonics since around 90% of driving forces come from the buoyancy force of sinking lithosphere in subduction zones. However, despite their vital role, it is still enigmatic how and where a subduction begins. In most of previous modeling studies a pre-existing weakness zone in the lithosphere, which is itself the product of plate tectonics, is a vigorous factor in subduction initiation [1–3]. One of the newly proposed scenario, which is independent to any pre-existing weakness zone, is mantle plume-induced subduction initiation that can also explain the beginning of the first subduction zone without the help of plate tectonics [4–6]. 3-D numerical models of plume-lithosphere interaction [5,6] indicated that arrival of sufficiently buoyant plume below a sufficiently old lithosphere can result in initiation of subduction. In study [5] we claimed that plume-induced subduction initiation triggered Plate tectonics and demonstrated that in the hotter early Earth plume-lithosphere interaction led to subduction initiation only if the oceanic plate was old. Arrival of plume beneath a young lithosphere produced episodic lithospheric drips in the early Earth.

In study [7] it was for the first time that the authors found evidence for mantle plume-induced subduction initiation in Caribbean region. They showed that at about 100 - 95 Myr ago the arrival of a large plume head, which formed Caribbean Large Igneous Province (CLIP), induced a new subduction zone in this region. They proposed that existing of 140 - 110 Ma plateau adjacent to an oceanic lithosphere created a favorable condition for subduction initiation upon arrival of mantle plume beneath the oceanic lithosphere and formation of a younger plateau at 100 Myr ago. They indicated that the main difference

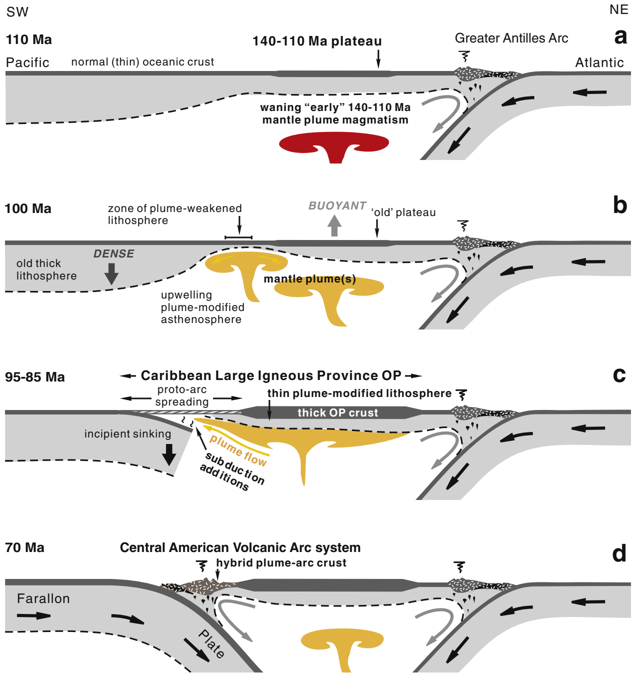

Figure 1: Schematic tectonic evolution of subduction zones in Carribbean between 70-110 Myr ago (from [7])

between their SW Caribbean plume-induced subduction initiation model from numerical models (e.g, [4]) is that in their model subduction initiates only on one side of the plume, not symmetrically all around the CLIP. They also claimed that this difference is because of subduction beneath the NE margin, which existed already some tens of million years before subduction initiation in the SW Caribbean (Figure 1).

In this project, we aim to investigate subduction initiation in the SW Caribbean at 100-95 Myr ago, using numerical models. Previous modeling studies (e.g., [5]) show that plume-lithosphere interaction can result in initiation of several subduction zones around the newly formed plateau. The question here is why did subduction initiate only on one side of Caribbean plateau? We explore whether the presence of subduction beneath the NE margin played a key role in the formation of one-sided subduction zone or existence of an old plateau near the plume head was the controlling factor in this process.

The other main unresolved problem for the Caribbean plate is how the history of subduction in the NE margin affected the plume-lithosphere interaction 100 Myr ago? When the Greater Antilles Arc formed in the NE margin at about 120 Myr ago,

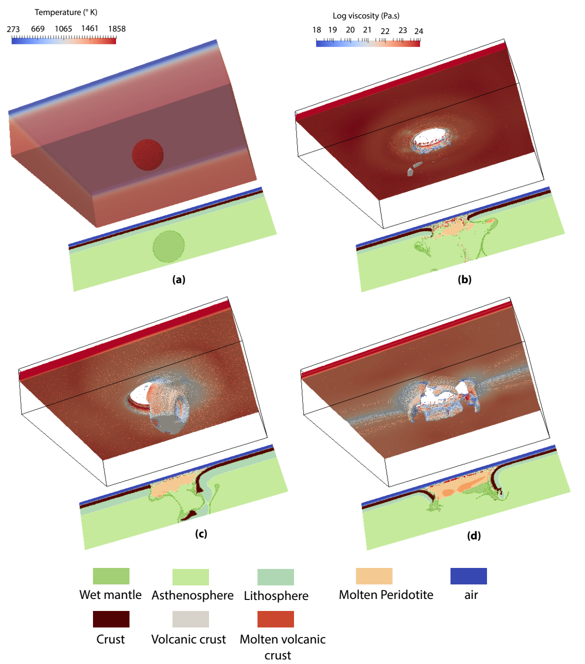

Figure 2: *Pilot numerical experiments of plateau lithosphere-mantle plume interaction. (a) Initial model set-up. The upper panel of (a) shows initial temperature field (color bar is shown at the left-top of figure) and the lower panel shows the composition of different layers of model. Different colors stand for different layers in the model, as indicated in the bottom of figure. (b) Results of reference model. (c) Results of a model with older oceanic lithosphere. (d) Results of a model in which the lithosphere is under extensional regime. The upper and lower panels of (b)-(d) show viscosity field of lithosphere and compositional field of a cross-section cutting through the middle of model, respectively. The color bar at the right-top of the figure indicates the viscosity field in (b)-(d).*

the overriding plate migrated rapidly to the NE as a result of rapid trench roll-back. This led to a large scale extension of overriding plate. Arrival of plume in the back arc of Greater Antilles Arc resulted in formation of Caribbean plateau and initiation of a new subduction zone in the SW. As a part of this project, we will study whether the strong upper plate extension and the presence of subduction in the NE margin deflected the plume or not. To establish 3-D thermo-mechanical models, we use I3ELVIS code, which is based on a combination of a finite-difference method, applied on a staggered Eulerian grid, and a marker-in-cell technique. Our modeling work consists of four parts: numerical models of interaction of a mantle plume with plateau lithosphere, modeling of arrival of a mantle plume below a plateau lithosphere under extension, models of mantle plume-lithosphere interaction in front of an active retreating subduction zone and modeling of lithosphere plateau-mantle plume interaction in front of a rolling back slab.

Figure 2 shows the model set-up (a) and model results (b-d) of our 3-D numerical model. The model consists of an oceanic plateau lithosphere, asthenosphere and a spherical plume (Fig. 2a). Results of our reference model (Fig. 2b) shows that interaction of a buoyant plume with thick plateau results in formation of a new plateau atop of older one. Model results of an experiment with older lithosphere shows formation of a retreating subduction(Fig. 2c). We also ran some models in which the plateau is considered to be under extensional regimes. Results of these models show that extension eases subduction initiation (Fig. 2d).

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More Information

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Project Partners

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